Physics Report

LBNC Meeting
Fermilab

Ryan Patterson
Elizabeth Worcester

February 19, 2018

Organization

High level coordination

Physics groups

Physics Coordination

Ryan Patterson
Deputy: Elizabeth Worcester

No org. changes since last LBNC meeting

Most recent additions (*c*. Sept 2017) shown **in red**

FD Sim & Reco
Chris Backhouse
Alex Himmel
Tingjun Yang

ND Physics
Mike Kordosky
Steve Manly

Long Baseline
Matt Bass
Dan Cherdack
Mayly Sanchez

BSM/Exotics
Alex Sousa
Jae Yu

High-*E* / NDK
Lisa Koerner
Vitaly Kudryavstev
Greg Pawloski

Low-*E* / SNB
Ines Gil Botella
Kate Scholberg
Alex Friedland

Physics TDR Volume

- **Albert De Roeck** and **Jon Urheim** are the volume editors
- Basic outline in place last summer. Physics WGs filled in more **detailed chapter outlines** ahead of January collaboration meeting

Contents

Physics TDR Volume – Key dates

- **May 2018**
  - Critical assessment of each of the many analyses and analysis components
  - Last practical opportunity to make drastic changes in approach or assumptions
- **September 2018**
  - Supplemental analysis documentation ready for review outside the relevant Physics WGs.
- **January 2019**
  - Analyses frozen
  - Final versions of plots, tables, values produced and propagated to the otherwise complete draft
- **February 2019**
  - Draft ready for **internal** review
- **April 2019**
  - Draft ready for **external** review

Milestones more generally

- Same milestones as shown in many past LBNC meetings, but with TDR milestones merged in explicitly
- Progress continues well (with recognition that some tough items are still to come)

DONE	Jan-17	Update long-baseline sensitivity calculations
DONE	Jan-17	Complete assessment exercise
DONE	Mar-17	Input to final task force reports
DONE	Apr-17	Launch and populate approved plots page
DONE	May-17	Incorporate tools developed for task forces into physics working groups
DONE	Jun-17	Define high-level TDR outline, scope
DONE	Jul-17	Establish TDR document workflow
DONE	Aug-17	Initial meeting with WGs conveners too discuss their detailed TDR outlines, scope
DONE	Sep-17	LArSoft integration complete where required
DONE	Nov-17	Determine physics analysis results needed for detector TDR
DONE	Jan-18	Second meeting with WG conveners to iterate on TDR outlines, groups' strategies, and scope through 2018
DONE	Jan-18	Assessment of required plots for TDR; define strategy for delivering any missing plots with target of May 2018
----------	TODAY	----------
PARTIAL	Mar-18	Determine methods to be used for primary results in physics TDR
	May-18	Assessment of required plots: follow-up
	May-18	Checkpoint: any high-level scientific goals requiring alternative strategies?
	Sep-18	Finalize physics results for detector and physics TDRs
	Sep-18	Supplemental internal documentation ready for review
	Jan-19	Final physics TDR
	Jan-19	Analyses frozen. Final plots and numbers assembled.
	Feb-19	Begin internal review of complete draft
	Apr-19	Final version ready for external review

FD Calibration Task Force

- **Sowjanya Gollapinni** and **Kendall Mahn** are TF coordinators
- Established last fall to develop a calibration strategy in time for inclusion in the TDR.
- Also a near-term charge: cryostat interface requirements

Slide from last LBNC meeting

Task Force Goals

Main Charge:

- What are our calibration-driven physics requirements? Associated impact on oscillation physics (and others)
- A Calibration strategy for the TDR timeline
  - Clarify assumptions about each source of uncertainty and how it is measured
  - Demonstrate reasonable arguments to achieve necessary precision

Sub Charge (near term):

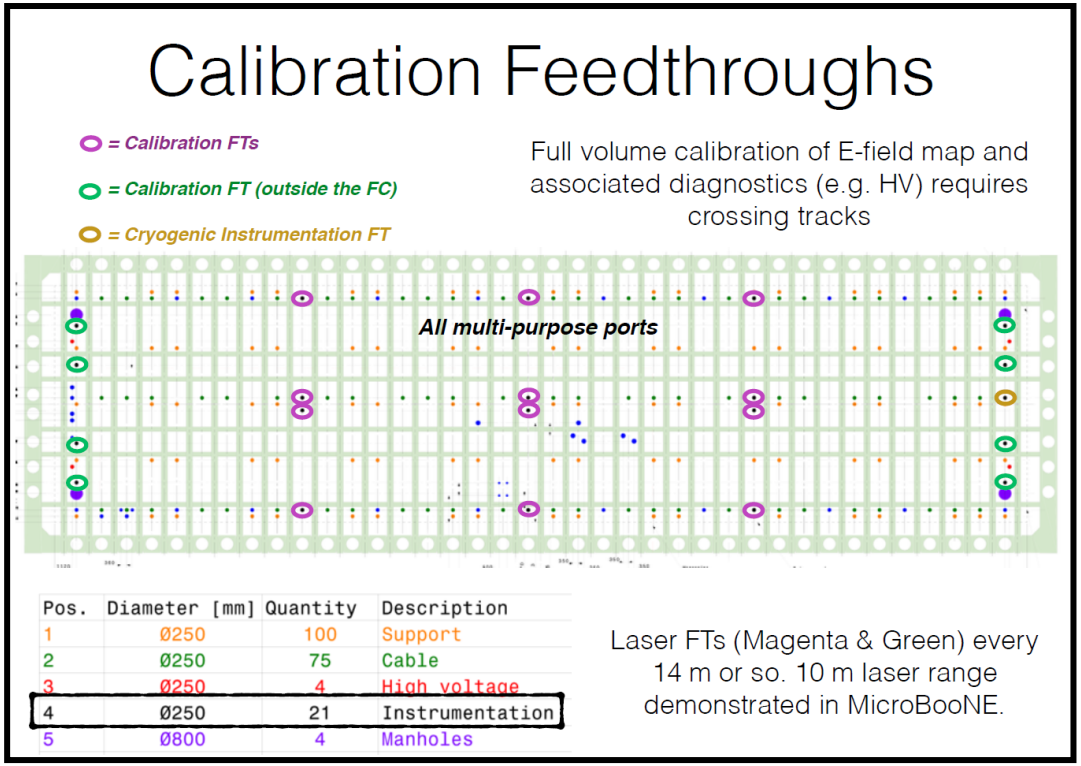
- Recommendation on Calibration hardware

(Unfortunately, timeline is awfully close to finalize Cryostat interfaces for calibration – We need to start thinking about it seriously starting NOW. Anything we say NO needs to be proved otherwise.)

FD Calibration Task Force

- Most of the TF work from September to December was on the near-term need to finalize cryostat penetrations
- Fruitful iterations between Calibration TF / Physics and Project
- Arrived at a flexible and minimal feedthrough specification that satisfies the cryostat engineering requirements

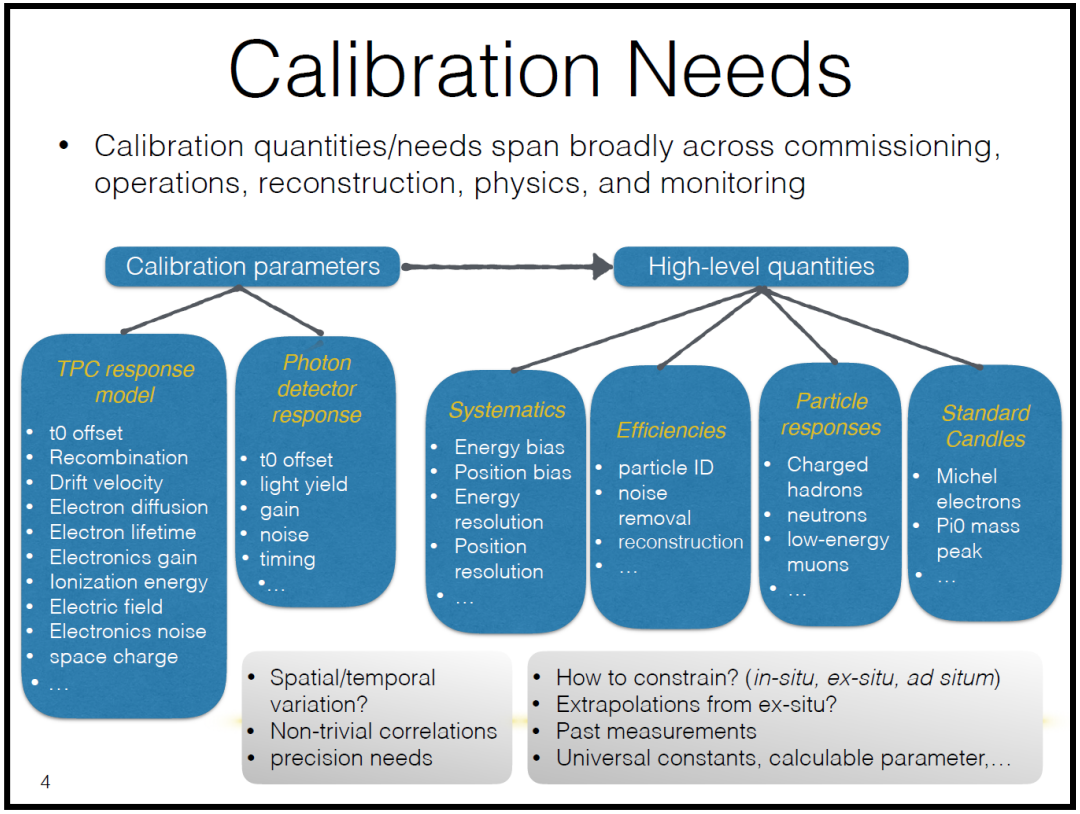
Slide from calibration discussions at collaboration meeting (Gollapinni, Mahn)



FD Calibration Task Force

- Now: Developing a concrete strategy.
- "Calibration" here covers a wide range of things, from low-level detector modeling (e.g., electronics gain) to high-level physics objects (e.g., EM energy scale)
- Knowledge gained can be highly correlated or degenerate if using any single probe.

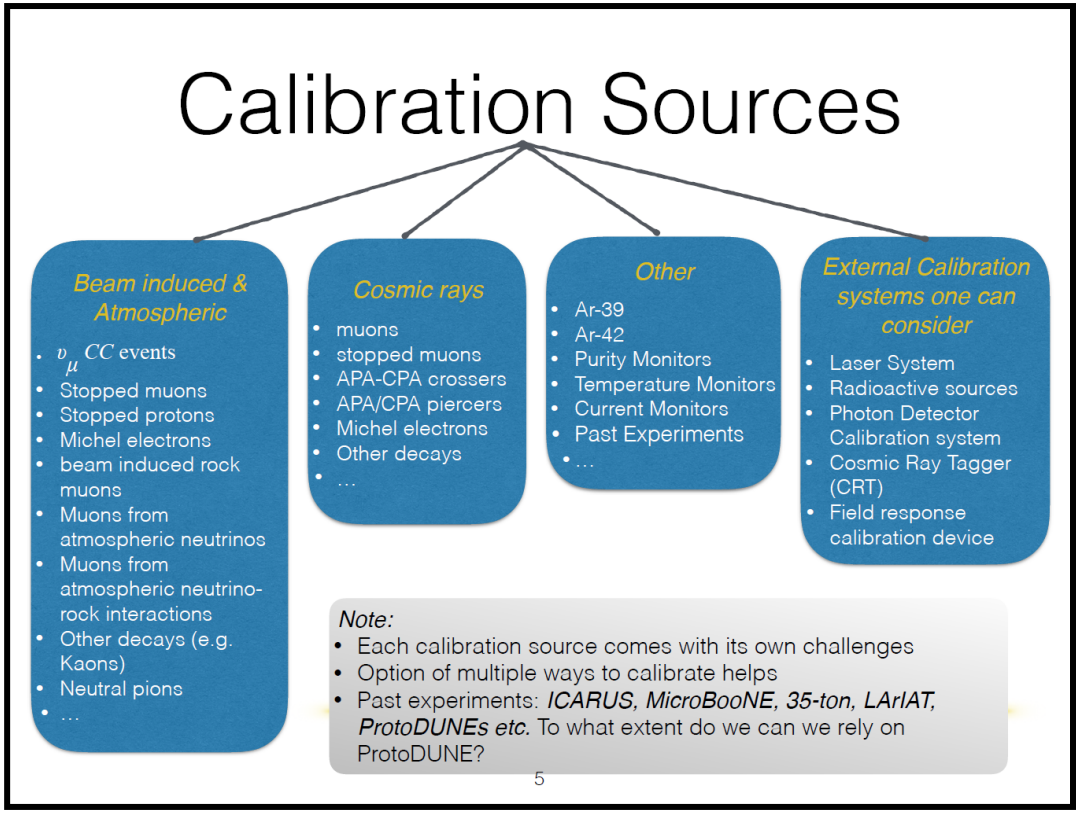
Slide from calibration discussions at collaboration meeting (Gollapinni, Mahn)



FD Calibration Task Force

- "Natural" calibration sources likely inadequate, hence attention given to external calibration systems
- In progress: exploration of many practical options (see chart below), impact on physics, mitigation of risk ("unknown unknowns")

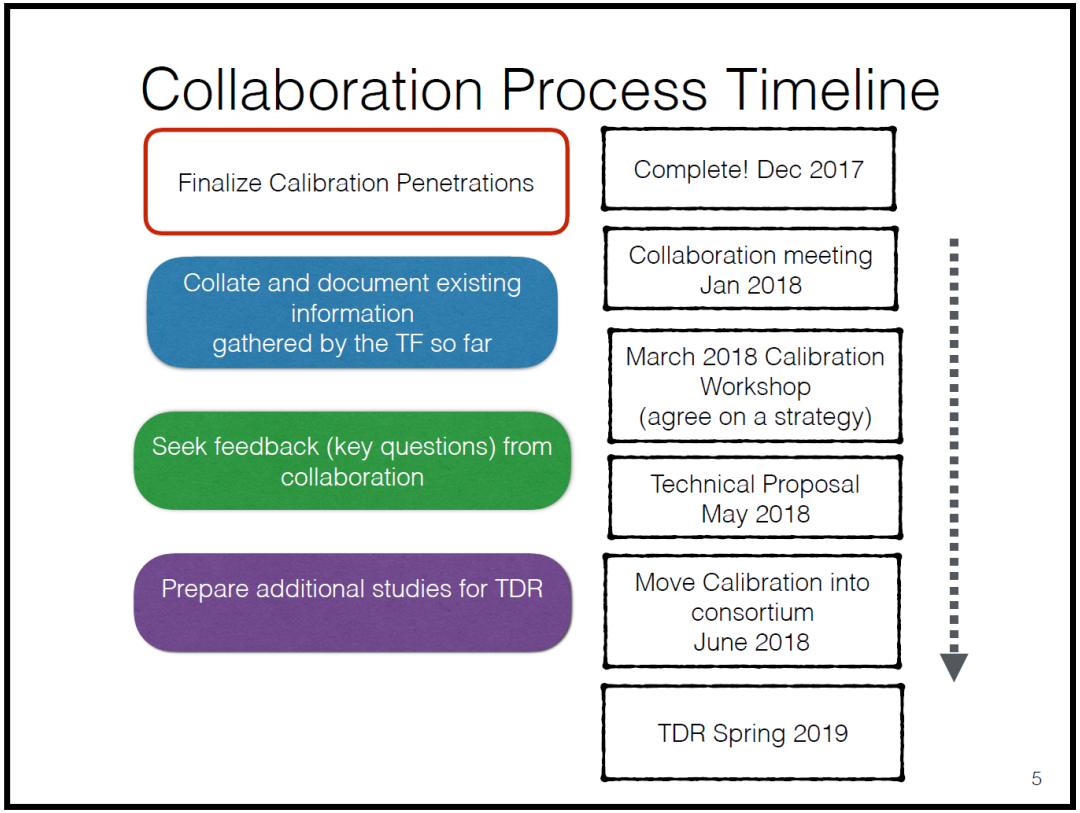
Slide from calibration discussions at collaboration meeting (Gollapinni, Mahn)



FD Calibration Task Force – Timeline

- Established a process for developing a strategy not unlike that used for the Near Detector
- March 2018 workshop is a key date: have a strategy worked out to be described in the Technical Proposal in May 2018.
- Migrate calibration into the DUNE Consortia process after.

Slide from calibration discussions at collaboration meeting (Gollapinni, Mahn)



Recommendations

2017-141 / 25-Oct-17 / Physics

The Physics group and Reconstruction groups need close communication with the Computing group. This is essential in order to complete various physics studies required for the Physics TDR in a timely manner and to ensure that necessary computing resources are available. In particular, different reconstruction techniques may require resources that are currently not in any plan.

We have met with Computing group coordinators several times since the last LBNC meeting to continue close communication. We have conducted surveys of the physics groups' current and projected computing needs, and we have provided the Computing group estimates for near-term production requests. We have exercised the new ticket-based production request system for our most recent large "core" samples. We will continue in these ways through the completion of TDR studies.

Recommendations

2017-142 / 25-Oct-17 / Physics

DUNE DP simulation and reconstruction under LArSoft framework should be brought at par with that of DUNE SP in order to make the physics cases for both the detectors on equal footing.

Progress is rapid with DUNE DP simulation and reconstruction. While the DP analyses must achieve enough sophistication to make meaningful statements about the technology's capability, we do not anticipate making precise relative statements between the performances of the SP and DP technologies, as the levels of sophistication will differ at the time of the TDR (e.g., MicroBooNE experience informing the SP simulation details and providing a long lead time for SP tools).

Recommendations

2017-143 / 25-Oct-17 / Physics

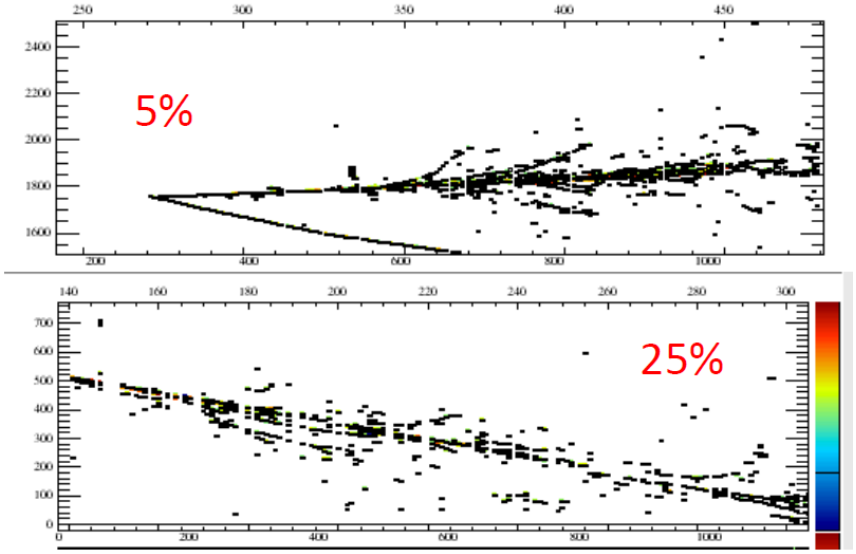
The effect of detector imperfections such as design parameters, as well as imperfections such wire breakage, LAr impurity, dead electronics, nonlinearities, calibrations, operational degradation as realized in operations, and any related detector conditions on key physics performance parameters should be discussed initially in the TP and in full detail in the TDR using either simulation, or experience from other closely related and relevant experiments, or both.

We have established an initial set of top priority detector variations to study. The first of these were processed in January and initially examined at the collaboration meeting.

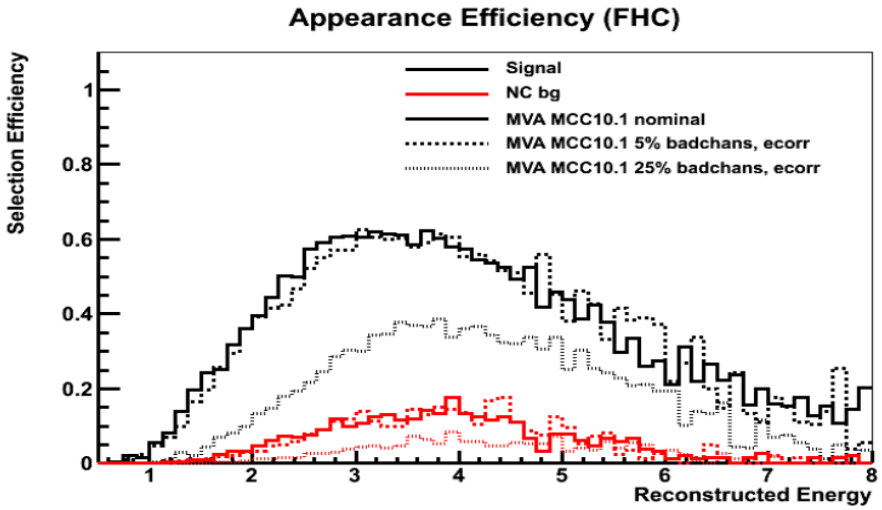
(more on next page)

- Initial variations chosen for their importance and their ease of implementation (hit the low-hanging fruit first)
  - Random dead channels ← *plots below: initial look via electron neutrino selections*
  - Dead channels correlated in electronics space
  - Lower HV (mimics effect of lower lifetime, too)
  - Altered noise (amount and model)

5% and 25% (!) dead channels



Traditional reco + MVA,
no algorithm or cut retuning



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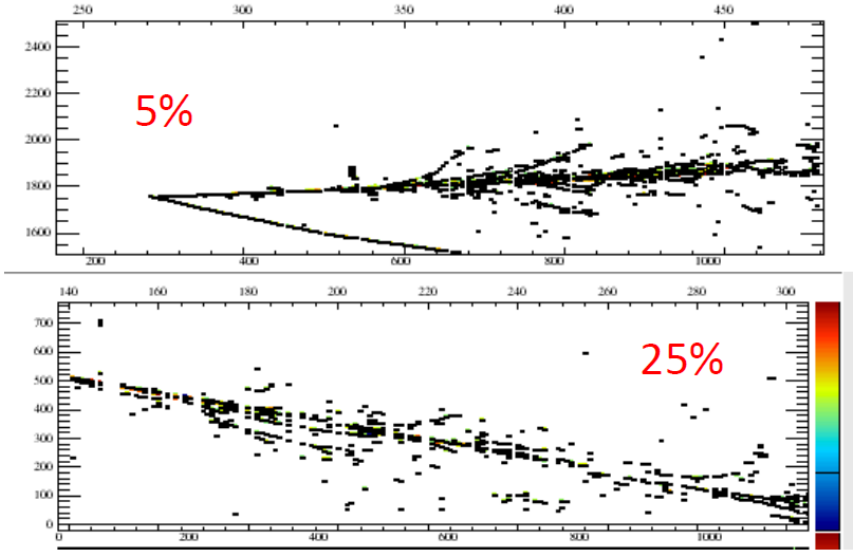
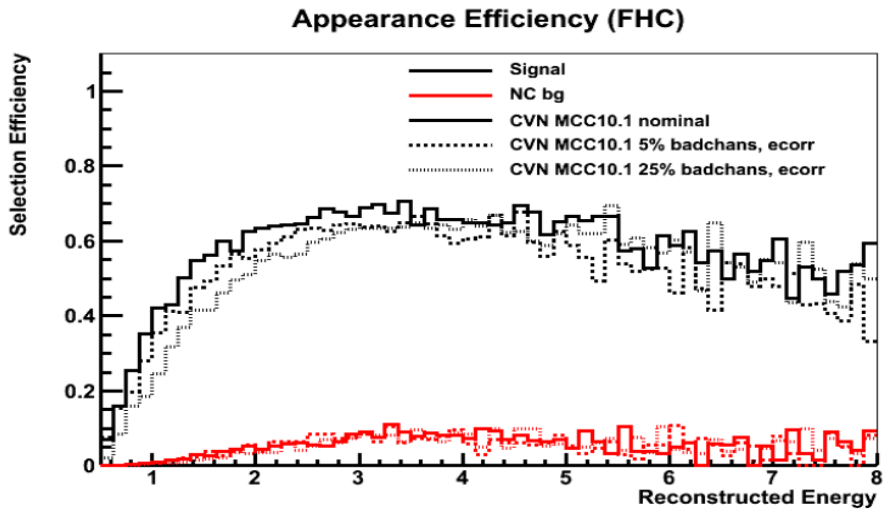


CVN selection,
no cut retuning



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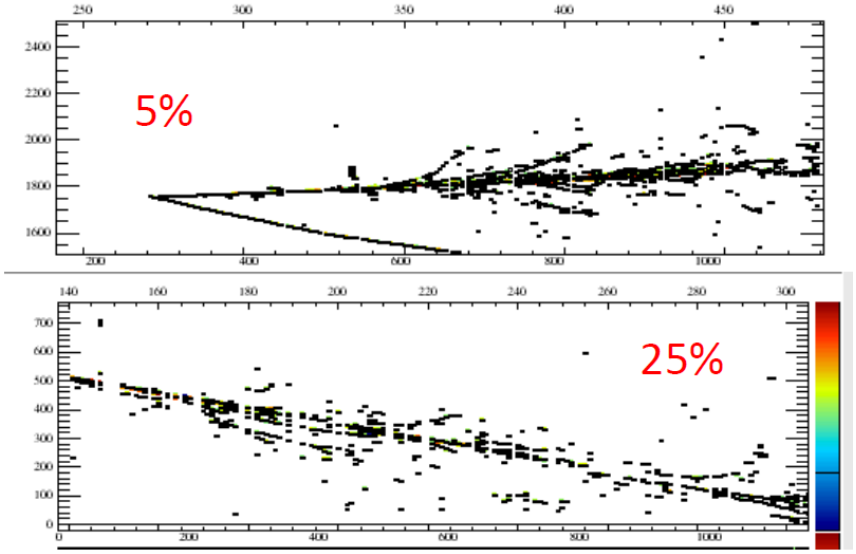
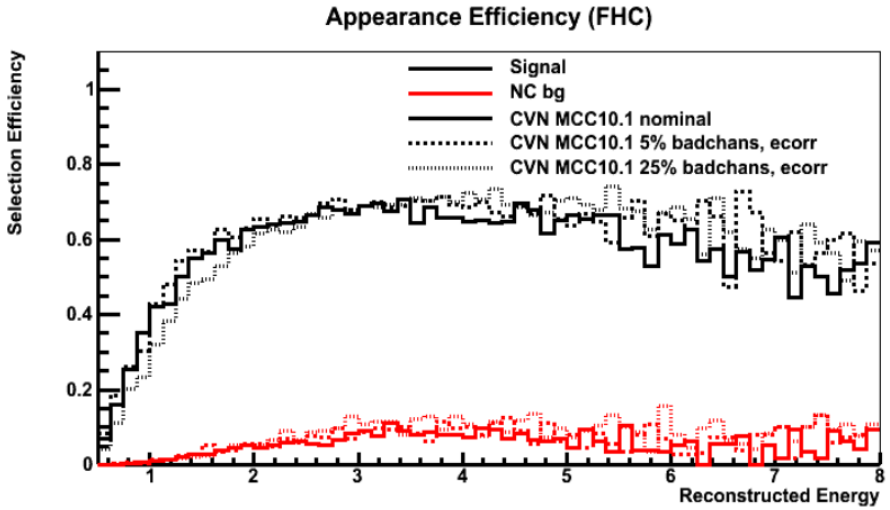


CVN selection,
simple cut retuning



No loss in performance at 5%.
Some loss at the very large 25%.
Propagation to physics parameter space to come.

Recommendations

2017-144 / 25-Oct-17 / Physics

There are various algorithms and tools that are being developed for SP and DP. A freeze date for a reference algorithm should be established for producing various physics plots as input for the TDR.

The current set of milestones includes such freeze dates. The final freeze date is Jan 2019, but several milestones over the coming year are related to this, including a checkpoint of algorithms and their performances in May 2018.

Additional highlights from the Physics WGs

LBL WG

CVN Event Selection Updates

Le. Whitehead & A. Radovic

CVN is neural network (CNN) approach to event classification. Recently retrained networks to include updates

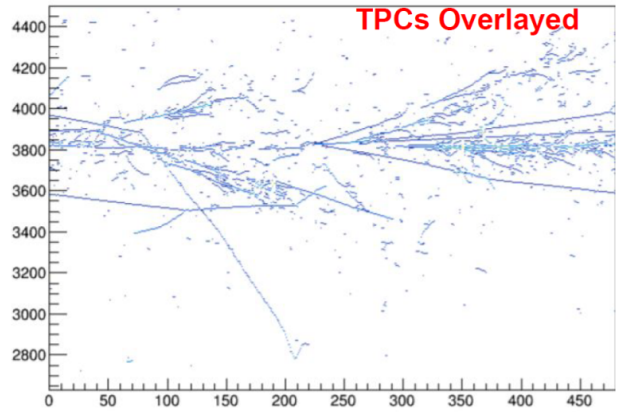
- **Global wire numbering**
- FV cuts during training & inference
- Flipped induction views

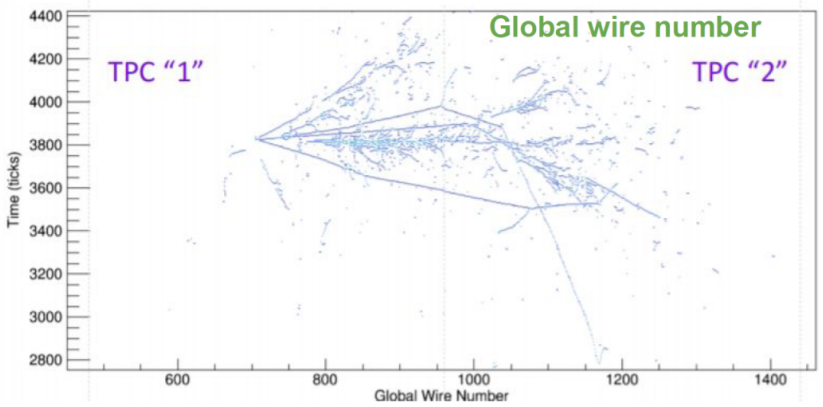
Leads to a **decrease** in sensitivity over previous results

- Still being debugged/evaluated
- Retraining in progress

Future plans:

- File format updates
- Framework (Caffe -> Tensorflow)
- Full detail vertex view
- Larger images
- Dual phase network
- Low E shower efficiency





Additional highlights from the Physics WGs

LBL WG

Energy Scale Systematics

S. Jones

Studying energy bias of the form:

$$E_{bias} = (1 + 0.02\sigma) * E_{reco}$$

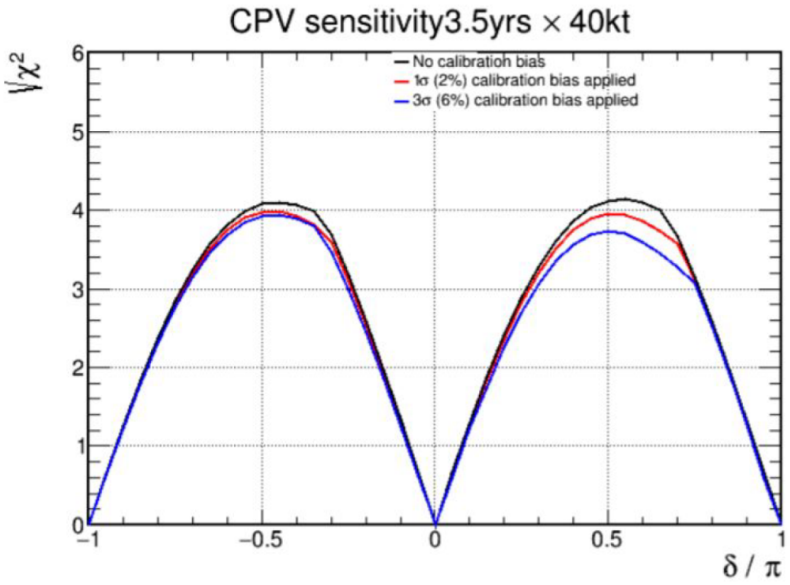
Verifying small effects of an energy scale systematic on CPV sensitivity seen previously.

- Fitter fits out calibration bias

Consistent with previous, GLoBES-based studies.

More studies planned:

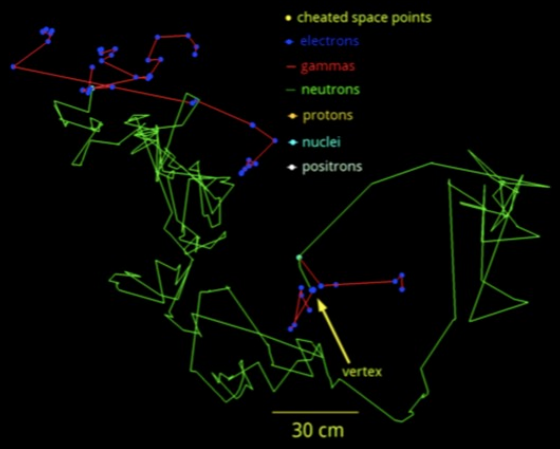
- Separating μ, e, hadronic scales
- Non-linear effects
- Combined fits w/ other systematics

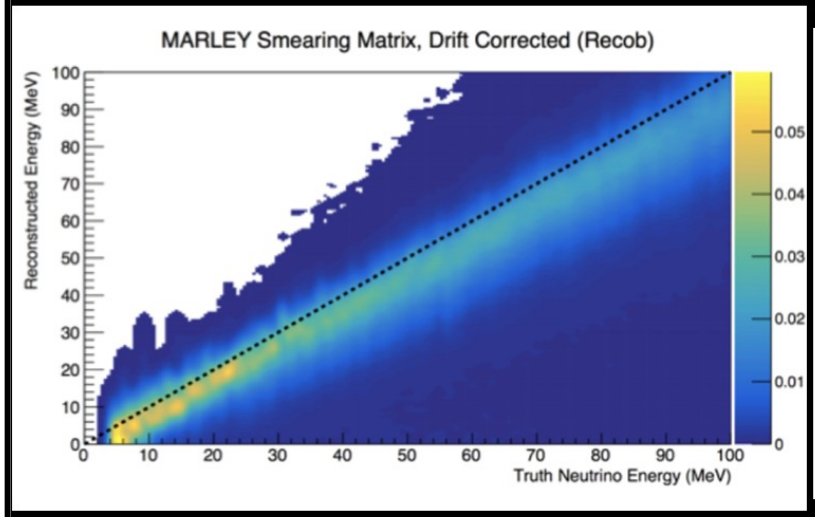


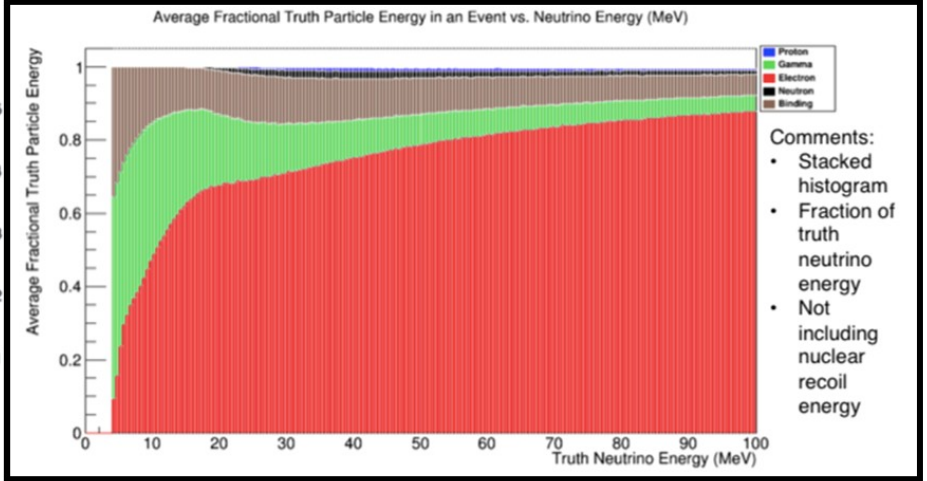
Takeaway is less about the results of this study and more about the ability to do such studies using the full fitting toolkit and about the ramp-up of brand new effort in the WG!

Additional highlights from the Physics WGs

SNB WG







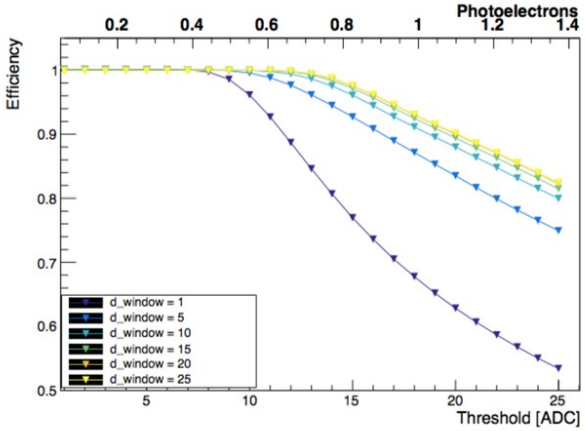
Additional highlights from the Physics WGs

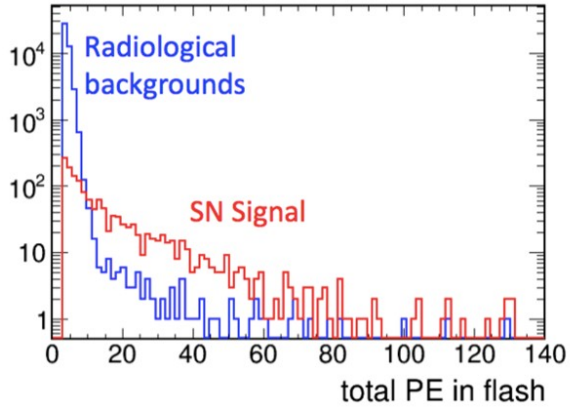
SNB WG

Photon Sim/Reco Progress : direct SNB relevance

SPPD

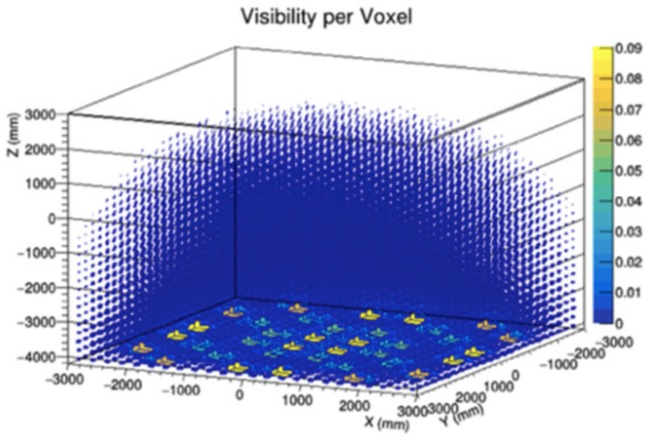
Electronics Simulation

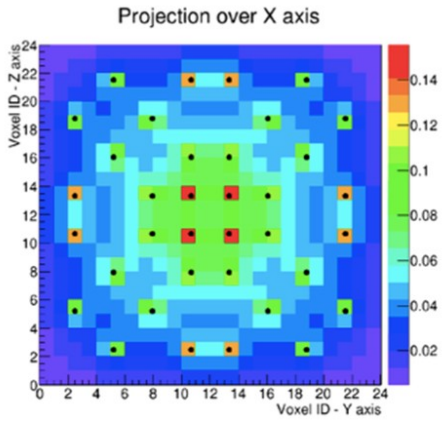




A. Himmel, V. Luzio, L.Rice

DPPD



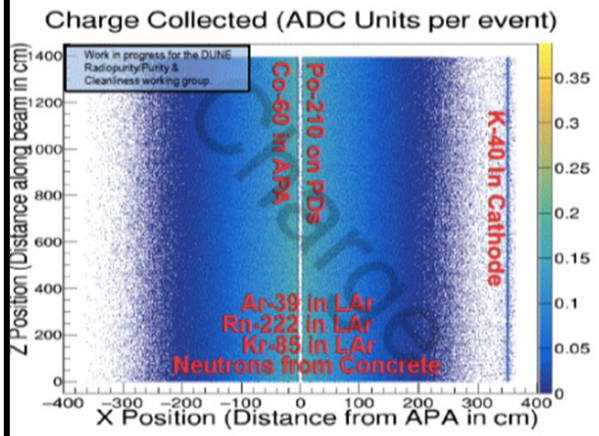


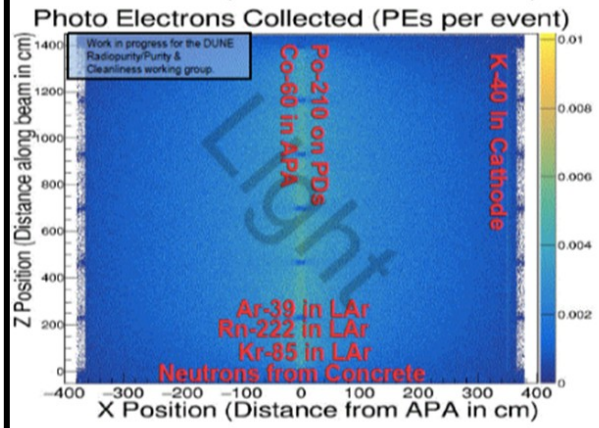
A. Chappuis, I. De Bonis, J. Soto

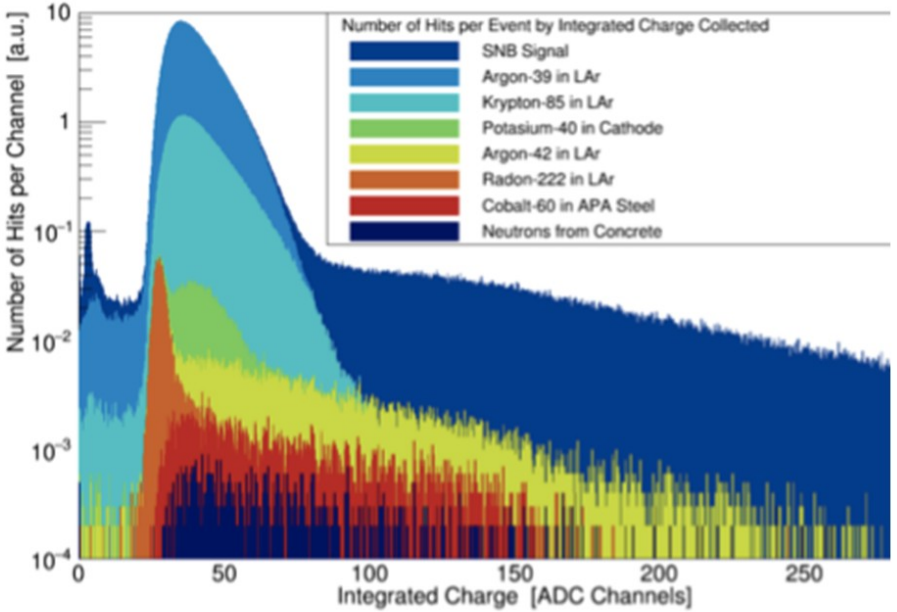
Additional highlights from the Physics WGs

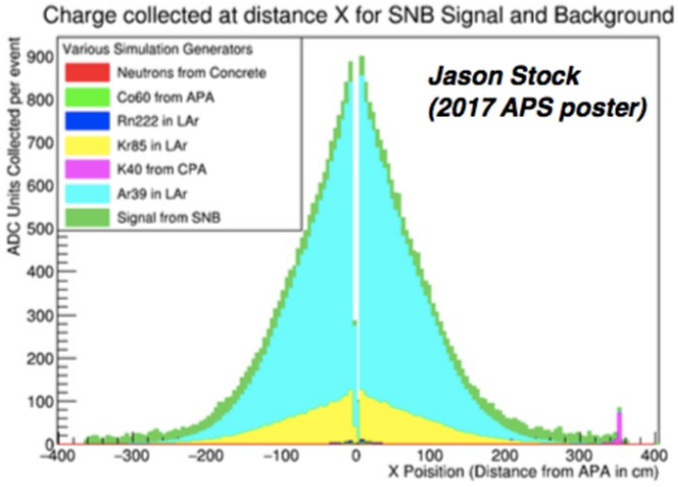
SNB WG

Radiologicals









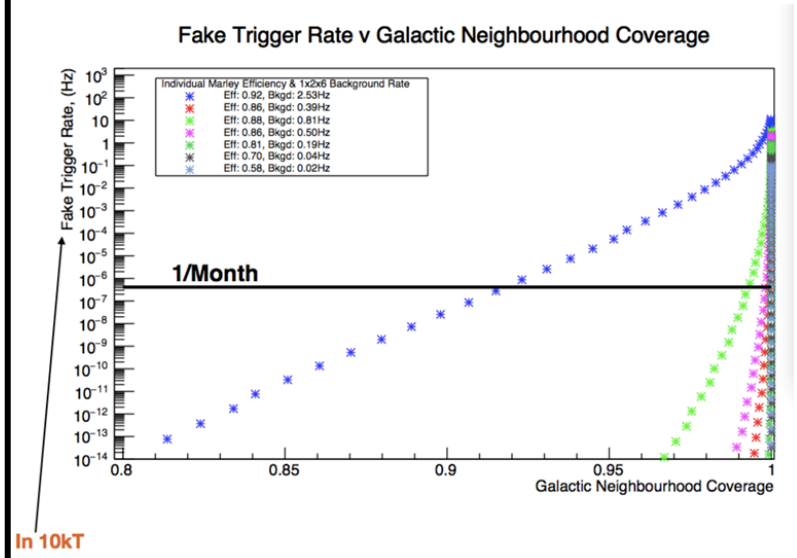
J. Reichenbacher, J. Stock

Additional highlights from the Physics WGs

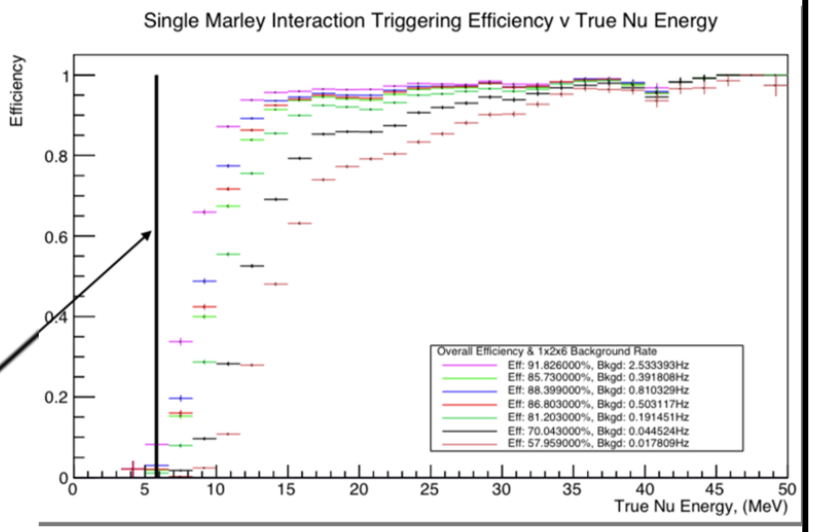
SNB WG

Joint Session with DAQ

G. Karagiorgi, A. Booth, K. Warburton



Encouraging preliminary studies on efficiencies, fake rates, latency vs distance to SN

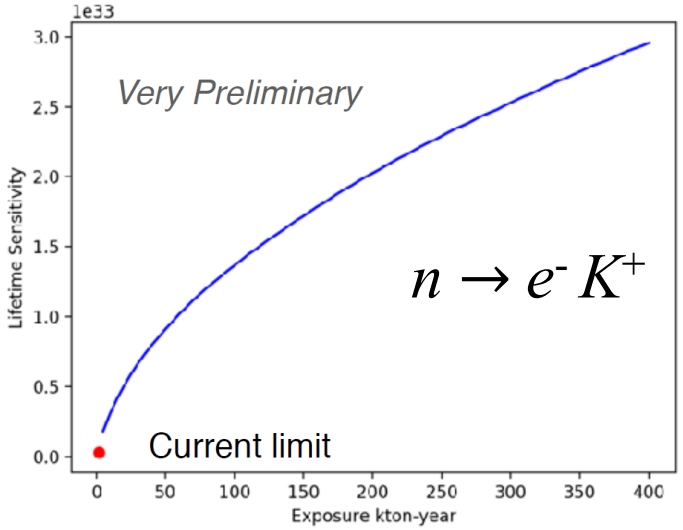


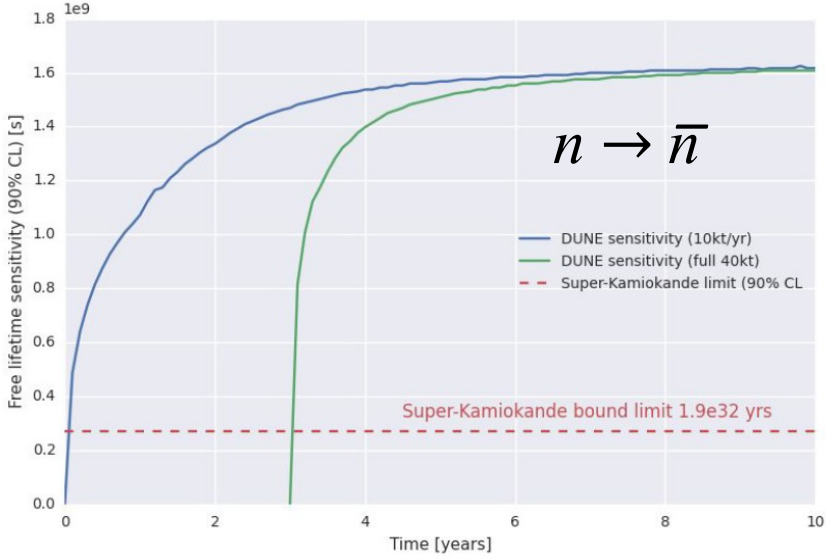
Threshold for SN interaction on Ar, 5.9MeV.

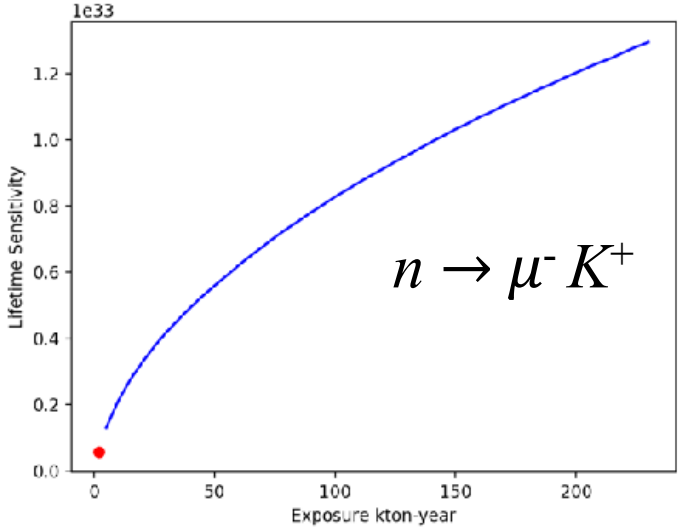
Additional highlights from the Physics WGs

NDK WG

- Tools originally developed for $p \to K\bar{\nu}$ now applied to channels at right
- n-$\bar{n}$ analysis well developed, moving to detector systematic studies
- Brand new effort identified for $p \to e\pi^0$ and for exploring alternative approaches to $p \to K\bar{\nu}$







Additional highlights from the Physics WGs

BSM WG

Analyses that are nearly ready

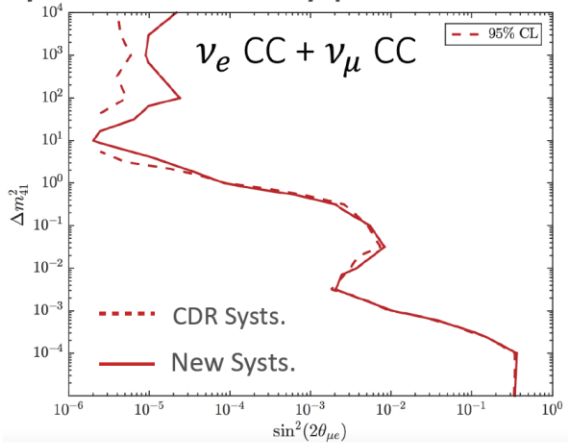
BSM Physics Highlights

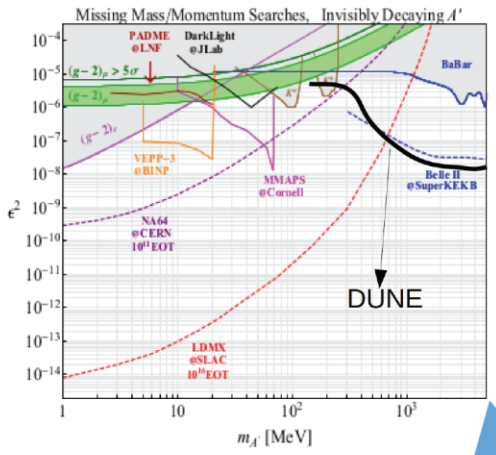
- Several topics converging, with preliminary versions of key plots in hand, namely:

Sterile Neutrinos

Inclusion of more realistic systematics

[M. Blennow, E. Fernandez-Martinez, A. Sousa]

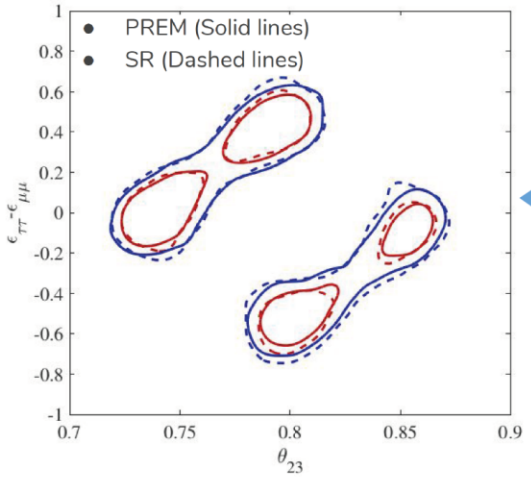




Low-Mass Dark Matter

Large-scale DM generation (10^9 events) - first comp. with other experiments

[A. Chatterjee, G. Brown, J. Yu]



Non-Standard Int.

Study of effects from matter profile models

[G. Barenboim, E. Fernandez-Martinez, C. Moura]

Additional highlights from the Physics WGs

BSM WG

Analyses making rapid progress

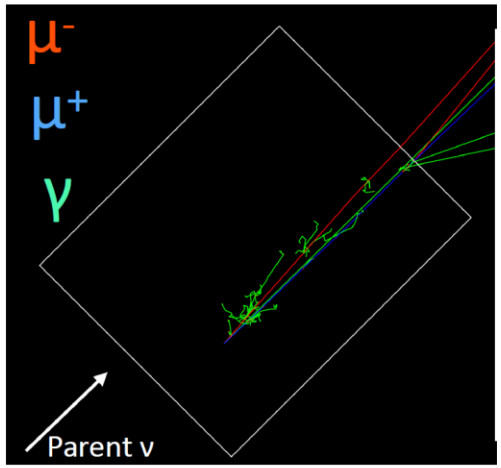
BSM Physics Highlights

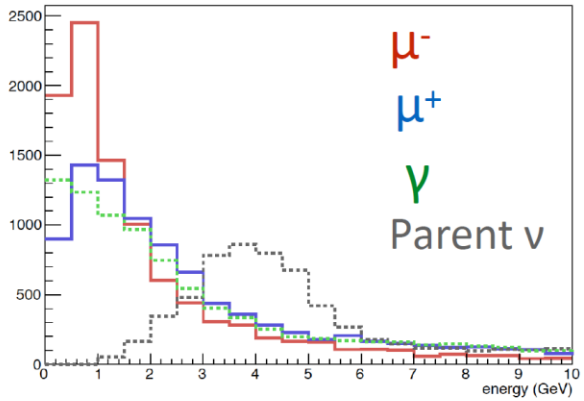
- Topics making quick progress:

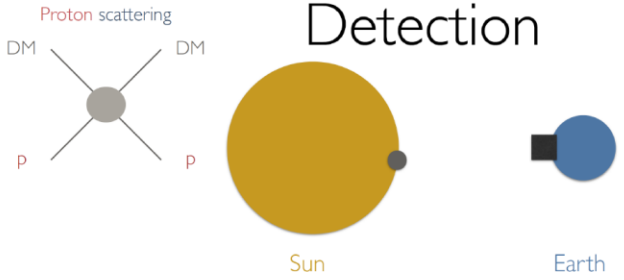
Neutrino Tridents

Simulation of signal and background events in ND LAr TPC completed. Bkg. studies started

[S. Gori, W. Altmannshofer, J. Martín-Albo, A. Sousa]







J. Berger, Y. Cui, Y. Zhao: JCAP 02 (2015) 005
Animation courtesy of J. Berger

Analysis Flow

- Benchmark dark matter flux models from theorists
- DM-Ar interactions provided by J. Berger
- GENIE takes care of the final state interactions
- GEANT4 detector material (LAr) simulation
- Simplified detector response simulation
  - Smearing matrices account for detector resolution and reconstruction efficiency
  - Conventional vs optimistic efficiencies
- Background estimation: mainly from neutral-current atmospheric neutrino-argon interactions
- Analysis and sensitivity studies

Boosted Dark Matter

New sub-group started during DUNE Physics Week! Plan for first sensitivities by May

[Y.-T. Tsai (Lead), J. Berger, Y. Cui, Y. Zhao, L. Necib, J. Assadi, B. Russell, S. Tufanli, G. Petrillo (FNAL), R. Hatcher, M. Convery, M. Graham]

Additional highlights from the Physics WGs

BSM WG

Newest ideas / efforts

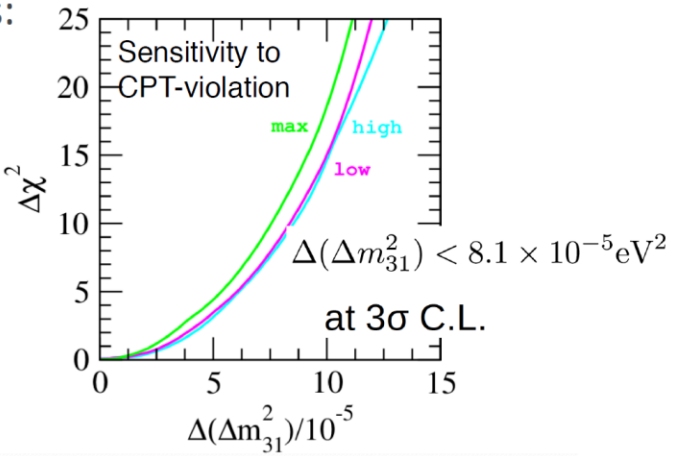
BSM Physics Highlights

- Potential new efforts:

CPT Violation

DUNE may improve current CPTV bounds by one order of magnitude

[C. Ternes, G. Barenboim, M. Tórtola]

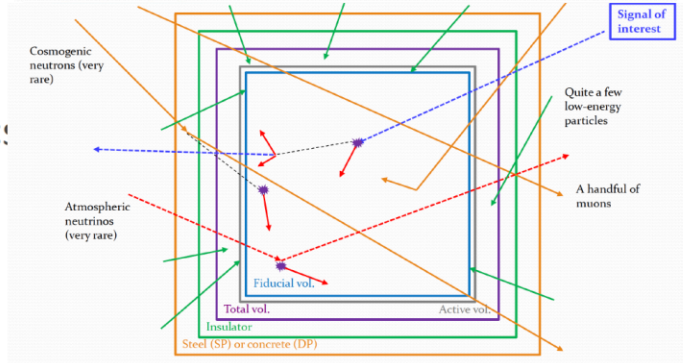


DM Searches with ProtoDUNE

Potential great opportunities for protoDUNE physics

[Doojin Kim]

Scattering \ v_{DM}	Non-relativistic ($v_{DM} \ll c$)	Relativistic ($v_{DM} \sim c$)
elastic	Direct detection	**Boosted DM (eBDM)**
*in*elastic	inelastic DM (iDM)	**inelastic BDM (*i*BDM)**



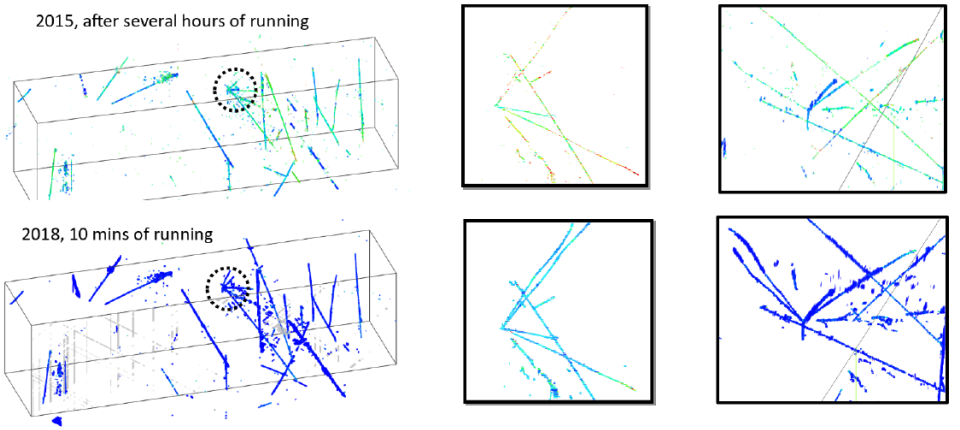
- Also ongoing efforts on non-unitarity, heavy neutral leptons, large extra-dimensions, etc.

Additional highlights from the Physics WGs

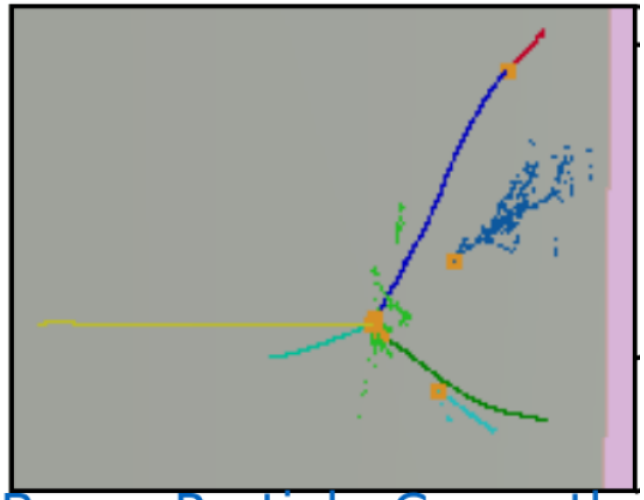
Reco WG

- In addition to reco work directly tied to FD analyses, general LAr TPC reco development continues to be lively *(will be for many years!)*
- Various examples flashed here…

Wire-Cell on MicroBooNE Data

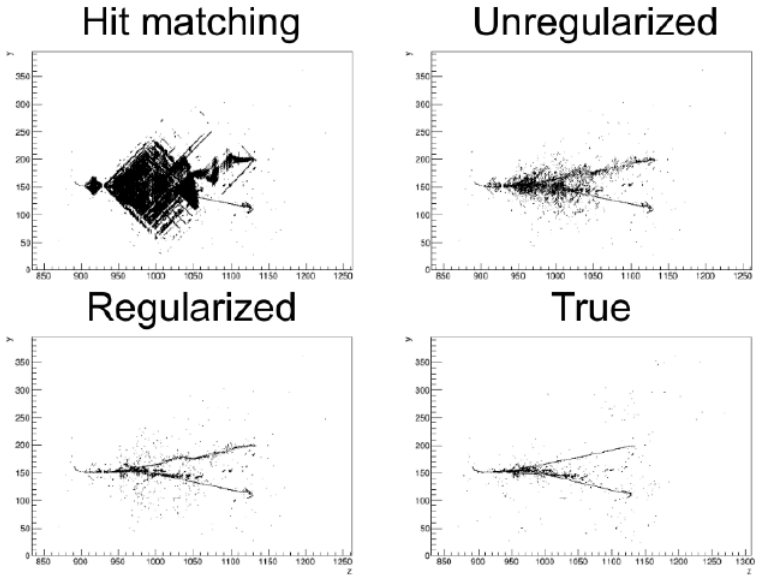


Pandora system, here applied to ProtoDUNE but applicable to FD



Beam Particle Correctly Reconstructed and Tagged

SpacePointSolver (direct-to-3D reco)



Closing notes

- **A few additional items** coming down the pipe soon *(a random sampling)*
  - Final XS reweighting tools for CAFAna (fitting framework)
  - Connections between lessons learned in Calibration TF and systematic uncertainty assumptions made in Physics WGs
  - Final list of astrophysical hypotheses that will serve as SNB test cases in TDR

- **Preparing for Neutrino 2018**
  - Not planning a sweeping overhaul of sensitivity estimates
  - That will come with the TDR
  - But it is a well-timed "intermediate goal" for WG activity